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INTERPRETING THE RESULTS OF ROCKET SOUNDING OF NOCTILUCENT CLOUDS

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ABSTRACT

The report critically considers the results of the interesting Swedish-American experiments on the rocket sounding of noctilucent clouds, admitting that they obtained important data. There is not always a conformity between the data of detectors, mounted on the rapidly moving rocket, and the true properties of the free atmosphere. The investigation of noctilucent clouds by rockets requires an elaboration of the interpretation theory of the measurement results. The report gives the considerations which should be taken into account in elaborating this theory. A greater number of particles on the day of the launch to the noctilucent clouds can be explained by the fact that dry dust specks flow around the rocket detector together with the oncoming air stream, while the dust specks with ice crusts, being of a larger mass, are not so easily carried away by the oncoming stream. We should also /80*

*Numbers given in margin indicate pagination in original foreign text.

take into account the increase of meteor activity from 7 to 11 of August (fig. 1),

The considered effect of the flow by the oncoming stream around the detector can also explain the increase of a relative content of small dust specks during the launch to the cloud. The report also indicates the influence of the boundary layer of strongly heated air at the rocket head and the detector, the scouring of the rocket and the change of the angle of attack.

1. As is well known, experiments on sounding of noctilucent clouds carried out in Sweden have yielded interesting results. In particular, the following facts have been discovered:

(a) a large quantity of dust particles is included in the matter composing noctilucent clouds;

(b) all larger cloud particles are surrounded by an ice crust;

(c) investigation of the chemical composition and physical structure of the dust particles confirmed their meteoric nature;

(d) a relation was established between the distribution of the number of dust particles and their size;

(e) the concentration of dust particles in a trap launched into a dense noctilucent cloud was much greater that when the same instrument was launched into the cloudless sky.

It should be noted that all these results applied to analysis of particles detected in a rocket trap, and in this respect the research method used in reference 1 satisfies high requirements. However, neither the preliminary (ref. 1) nor the later publications (ref. 2) considered the problem of the correspondence between the properties of particles taken in the traps and particles of noctilucent clouds in the free atmosphere. However, it is known that there is by no means always an unambiguous correspondence between the readings of sensors mounted on a rapidly moving rocket and the true properties of the free atmosphere. In order to establish such a correspondence it is necessary to make a special analysis and perhaps formulate a complex physical theory (ref. 3).

We believe that the use of rockets for investigation of noctilucent clouds also requires formulation of a theory of interpretation of the measurement results. In this report considerations are presented which we believe should be taken into account when formulating such a theory.

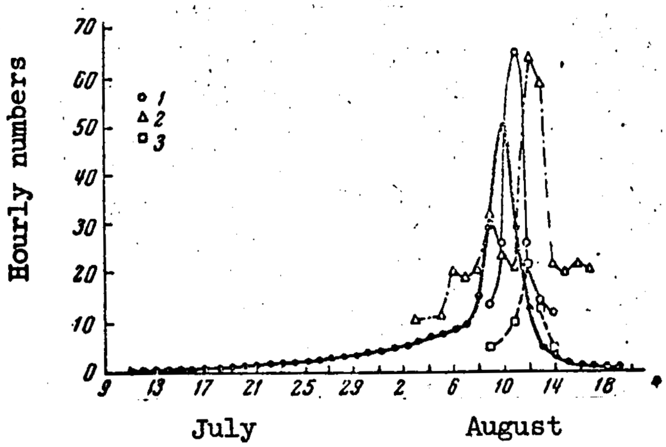
2. We will begin with the results of finding "e". It must be taken into account that during motion of a rocket in the dry layers of the atmosphere the very fine light cosmic and meteor dust always present there mostly flows around the rocket trap together with the oncoming air flow. However, if the rocket is moving in the very moist air of the mesopause, when the dust particles may be centers of condensation or sublimation or centers of precipitation of moisture, the number of particles precipitating in the rocket trap should increase, because the dust particles, surrounded by a layer of moisture, are many times greater in mass than dry dust particles. Due to the considerable mass and great speed of motion of the rocket (the trajectory data cited in references 1 and 2 show that the rockets passed through the mesopause layer at a velocity of about v = 800 m/sec), these relatively massive particles are poorly /81
entrained by the air current flowing around the trap and as a result of considerable kinetic energy relative to the body of the rapidly moving rocket

penetrate the protective layer of the trap and settle in it. This is a partial explanation of why on the day of launching, when noctilucent clouds were present, the number of particles in the rocket trap was considerably greater than during launching in the clear sky.

3. There is still another factor which forces us to exercise caution with respect to the final formulation of the result mentioned in "e". This factor has a completely different character: it is unrelated to the theory of interpretation of measurements made on rapidly moving rockets and is instead related to the field of meteor astronomy. We have in mind the variability of meteor activity with time, associated with both the meteor background (sporadic meteors) and meteor streams. In this respect the dates of launching of the sounding rockets in Sweden (7 and 11 August 1962) must be regarded as fortunate from the point of view of investigation of meteor matter in the earth's atmosphere, but less fortunate for study of the nature of noctilucent clouds.

It is known that there is a diurnal and annual variation of the number of sporadic meteors, and this must be taken into account in a comparison of the quantity of meteor matter detected in the atmosphere on different days. The curve of annual variation (ref. 4) indicates a considerable increase (by a factor of 2-3) of the number of sporadic meteors in the first half of August in comparison with the other months of the year.

Data on meteor streams cause us a still greater concern. After the η-Aquarids stream in early May (we note that this time also coincides with the onset of the main season of noctilucent clouds), nighttime meteor activity remains very low until late in July (ref. 4). However, the period covering the end of July and August has one of the greatest abundances of meteors of any season of the year (ref. 4), but the activity of noctilucent clouds is already



Meteor activity.

1, Öpik, 1921; 2, radar observations, 1950;

3, visual observations of meteors 1944-1947.

decreasing by this time. The period mentioned includes two large streams σ-Aquarids (maximum about 28 July) and Perseids (maximum 10-14 August). In the period of the Perseids stream there is an appreciable increase of the number of meteors beginning only on 8-9 August (see illustration, reproducing figure 129 of Lovell's book (ref. 4)), but by 11-12 August increasing by a factor of 7-10.

Since the presence of meteor matter in the upper layers of the atmosphere (in the zone of "combustion," that is, evaporation of meteors, 70-90 km) already has long been a commonly accepted fact, it may be expected in advance that a trap carried by a rocket to heights of 80-100 km, if it operates effectively, necessarily shows the presence of meteor dust in the atmosphere. Moreover, if we use available data on variations of the number of meteors (see /82 illustration), it is possible to predict that on 11 August 7-10 times more meteor matter will be detected than on 7 August, due to an increase of the activity of the Perseids. Thus, a large part of the observed increase of meteor matter in the samples taken on 11 August (two or three orders of magnitude greater than on 7 August) can be attributed to the annually repeating characteristics of the Perseids stream.

However, the appearance of noctilucent clouds precisely at the time of the maximum of the Perseids (11 August) was pure coincidence, because the maximum of the frequency of appearance of noctilucent clouds, as shown by numerous observations in the USSR in the IGY and IQSY periods, falls in the first half and middle of July, that is, in a period of low meteor activity.

4. The particle-size distribution obtained by the authors of references 1 and 2 also supports this interpretation (see "b") of rocket experiments on the study of noctilucent clouds. On the days of the launchings, when noctilucent clouds were present, the relative content of the finest particles increased in the rocket trap. This result fully corresponds to the above-mentioned interpretation of the results of these experiments.

On days when the upper atmosphere is dry and devoid of noctilucent clouds, the finest and light dry particles "fly around" the head of the rocket with the air current and do not enter the trap. Only a relatively small number of the largest dust particles, having a high inertia, break through the protective layer and settle in the trap. On days with noctilucent clouds, as a result of the high humidity of the high layers of the atmosphere, a large quantity of moisture, possibly even exceeding the mass of the dust particles themselves, is precipitated on them and facilitates the entry of even the tiniest dust particles into the trap.

5. During ascent of the rocket into noctilucent clouds appreciable annular traces of moisture remain only around some of the particles in the trap,

whereas they are not noticeable around others. However, this result does not mean that noctilucent clouds consist of a considerable number of dry dust particles in addition to particles which can be regarded as moist particles. It must be remembered that in the case of a high velocity of movement of the rocket ($v = 800$ m/sec, see "b") a boundary layer of strongly heated air is formed near the head of the rocket and trap; upon entering this layer the particles of the noctilucent clouds rapidly lose their moisture as a result of energetic evaporation. Therefore, very many particles, upon "penetrating" the heated boundary layer and entering the rocket trap, are deprived of traces of moisture. Only the largest droplets or crystals retain significant traces of moisture upon entry into the rocket trap and annular traces remain on it.

6. Important conclusions have been drawn by the authors of references 1 and 2 from a comparison of the results obtained during sounding of a noctilucent cloud (11 August) and during launching of a rocket with the same instrumentation into a clear sky (7 August). Above (see "c") we already have noted one of the circumstances making the conditions for these two experiments not entirely comparable (strong variability of meteor activity in the period between the two rocket launchings). There are also other circumstances distorting the comparability of the conditions of these two experiments: the presence of yawing of the rocket and change of the angle of attack of the rocket (on 11 August 1962 the angle of attack was greater). The change of both of these aerodynamic factors, associated with the flight regime of the rocket, can change the regime of flow of the oncoming air current around the rocket, and therefore there can be a change of the conditions for entry of light and more massive (moist) particles into the trap.

REFERENCES

1. Witt, G., Hemenway, C. L. and Soberman, R. K. Collection and Analysis of Particles from the Mesopause. Proc. Fourth Int. Space Sci. Symposium, Warsaw, June 1963. Amsterdam, North-Holland Publ. Co., 1964.

2. Hemenway, C. L., Soberman, R. K. and Witt, G. Sampling of Noctilucent Cloud Particles. Tellus, Vol. 16, No. 1, pp. 84-88, 1964.

3. Shvidkovskiy, Ye. G. Rocket Meteorological Measurements (Raketnyye meteorologicheskiye izmereniya). Trudy Tsentral'noy Aerologicheskoy Observatorii, No. 29, 1960.

4. Lovell, B. Meteor Astronomy (Meteornaya astronomiya). Fizmatgiz, 1958.